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THREE NEW SPECIES OF SEVEN-GILLED HAGFISHES (MYXINIDAE, *EPTATRETUS*) FROM THE PACIFIC OCEAN

By

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Abstract: Three new species of hagfishes (Myxinidae, *Eptatretus*) from the Pacific Ocean are described, and compared with *E. cirrhatus*. All four species have seven pairs of gill pouches and associated external openings. Of the new species, *E. carlhubbsi* is known from Molokai to Guam, north-central Pacific, *E. laurahubbsi* from off south-central Chile, and *E. strahani* from near Lubang Island, Philippines, South China Sea. *Eptatretus cirrhatus* occurs in the Australian-New Zealand area. Methods used in examination of hagfishes are described, and sensory (lateral line) canals are delineated and discussed briefly.

Introduction

This study of seven-gilled hagfishes (genus *Eptatretus*) from the Pacific Ocean is one of a series resulting largely from the specimens and data accumulated under direction of the late Carl L. Hubbs. Herein we describe three new species, present new data on *E. cirrhatus* (Bloch and Schneider 1801), offer suggestions for initial preservation of myxinids to provide good study material, and discuss methods useful in the taxonomic study of hagfishes. We also offer figures and a brief description of the sensory canals found in the ocular regions of two of the four species.

Discussion

Our examinations have shown that species of *Eptatretus* from the Pacific Ocean have six to fifteen pairs of gill pouches and corresponding external apertures. The three new species described below, with *Eptatretus cirrhatus,* comprise a group having seven pairs of gill pouches. One aberrant specimen has eight pouches on each side, but with corresponding apertures arranged abnormally. Our rather limited counts (22 pairs) from the three new species may not reflect extremes of variation, but the number of gill apertures in *Eptatretus cirrhatus* appears to be constant—seven pairs in 48 specimens. In 44 counts from 22 specimens of the three new species, the only variation from seven was the specimen cited above (further discussed and figured below).

Counts of six apertures for *Eptatretus cirrhatus* recorded in the literature apparently resulted from a confusion of species. Günther (1870) stated that the species had "six or seven gill openings on each side," but he listed specimens from South Africa (*E. hexatrema* Müller, 1834) and Japan (*E. burgeri* Temminck and Schlegel, 1850). Species from these areas commonly have six pairs of gill openings. Referring to *Eptatretus cirrhatus,* Waite (1909) stated, "The gill-openings appear to be seven in number, but I have seen an

example in which there were but six openings on one side, though seven were present on the other." A variation of one per side is common in species having ten or more gill pouches, such as *E. deani* (Evermann and Goldsborough 1907) and *E. stoutii* (Lockington 1878). Also, it is possible that Waite had an abnormal specimen in which two pouches shared the same opening (see above). Strahan's (1975) finding of "seven (rarely six) pairs of branchial apertures" for *Eptatretus cirrhatus* may have been influenced by Günther's or Waite's accounts.

Regan (1912) listed a species with "7 gill openings: on each side two rows of 8 teeth. Southern Pacific" as *Heptatretus banksii,* and placed in its synonymy *Homea banksii* Fleming 1822, and *Bdellostoma heptatrema* Müller (1834). Regan's total count of 32 teeth is much lower than that of any of the four species treated herein (Table 6), and may indicate an erroneous count or an undescribed species. Regan may have counted three fused median teeth (multicusps) on each row as one, thus reducing the count to 32 from a possible 40. This would have been much nearer our minimal count of 43 for *Eptatretus cirrhatus,* under which we synonymize the above three names.

Species of *Eptatretus* having seven gill apertures are not restricted to the Pacific Ocean. Fernholm and Hubbs (1981) listed a species having seven apertures from the Caribbean Sea. Fernholm (1982) has further described it as new.

In general, we concur with Fernholm and Hubbs in terminology, with but minor variations. We believe the term "dental muscle" is more appropriate than "tongue," "lingual," or "club-shaped muscle" in reference to the firm elongate complex of muscles and cartilages which constitutes the feeding mechanism of myxinids. Apparently the term "tongue" was first used by Müller (1834), but we concur with Ayers and Jackson (1900) that the entire apparatus in no way resembles a tongue. They stated, "The homology of this organ with the vertebrate tongue has never been discussed, nor do we know of any effort to determine the true nature of this organ." Dawson (1963:248, fig. 11) provided a detailed analysis and figure of the structure, and of the "teeth" and "jaw apparatus." She concluded (p. 253) that it was unwise to make any definite assumptions concerning homologies of the cartilages and muscles.

There are two pairs of anterior and posterior sets (series) of sharply pointed, laterally flattened, horny structures in the oral cavity which are embedded in a dental plate. These structures cut and scrape food into ingestible portions when everted and retracted by the dental muscle. Although the term "teeth" has been widely used in reference to these structures, they are unlike the teeth of other vertebrates, being composed entirely of keratin and devoid of calcification. Dawson (1963:247) concluded that, "It is most likely that there is no phylogenetic connection between these teeth and calcified teeth, and that they are an individual adaptation to a parasitic mode of life."[1] For descriptive and statistical purposes, we prefer the terms unicusps and multicusps to differentiate between single and composite teeth—the latter formed by the fusion of two or three unicusps. We consider the number and arrangements of both the multicusps and unicusps to be a significant species character.

Materials

Collection data and disposition of specimens examined in this study are listed in the treatment of each species. Institutions which have furnished study material, or in which type specimens have been deposited, are: Bernice P. Bishop Museum, Honolulu, Hawaii (BPBM); United States National Museum, Washington, D.C. (USNM); Scripps Institution of Oceanography, La Jolla, California (SIO); California Academy of Sciences, San Francisco (CAS); Museum National d'Histoire Naturelle, Paris, (MNHN); University of the Philippines Zoological Museum, Diliman, Quezon City, Philippines (UPZM); Australian Museum, Sydney (AMS); Zoological Institute, Academy of Sciences, Leningrad (ZIN).

Methods

The methods of measuring and counting described herein represent original methods as well as some used by prior authors including Dean (1904), Nani and Gneri (1951), Richardson (1953), and Strahan (1975). Fernholm and Hubbs (1981) reported many of these methods in their study of the eastern Atlantic *Eptatretus.* When

[1] Hagfishes are not parasitic; they scavenge dead or moribund fishes and invertebrates.

the senior author, in collaboration with the late Carl L. Hubbs, began work on the myxinids (in 1969), it was obvious that no standard criteria existed for the study of hagfishes, which lack the jaws, opercula, rayed fins, scales, gill rakers, and bones found in most fishes. Early workers applied different names to the same anatomical characters, defining them differently or not at all, and often not mentioning the methods used in measuring and counting. Therefore, it was difficult to correlate or compare data of different authors, and taxonomic confusion resulted. We hope that the methods proposed and defined below will provide future investigators with a standard by which hagfish species and specimens may be readily compared and identified.

Proper treatment immediately after capture is of particular importance in rendering specimens suitable for study. Often too many live hagfish are crowded in jars of preservative, resulting in coiled or bent bodies, usually heavily coated with slime (mucus) and difficult to measure or count. The copious secretion of slime, characteristic of the family Myxinidae, is dramatically curtailed by prompt immersion in fresh water, preferably warm. This rapidly kills the hagfish and prevents further extrusion of slime, which otherwise continues for several minutes even in formalin. Any remaining slime may be removed with paper or cloth towels, and the specimens should then be laid straight in a suitably large container of formalin until fixed. If a specimen is too large for a flat pan, it should be coiled smoothly in a 3–5-gallon container, taking care not to deform the snout or twist the body, and covered with formalin. This treatment produces fairly straight specimens with a minimal coating of slime, and greatly facilitates accurate counts and measurements.

Since fresh hagfishes deteriorate rapidly, preservation should be prompt. Color photos or notes should be made to record pigmentation, and tissue or blood desired for biochemical or chromosomal studies should be taken prior to immersion in formalin. We find that initial freezing prior to chemical preservation may cause softening of the tissue and collapse of eggs and internal organs, but it may be preferable to crowding into a too-small container. Due to the many body openings, we consider it unnecessary to slit the skin or to inject preservatives; hagfishes are so soft that the skin may tear and some underlying tissues may come apart, causing difficulty in subsequent measures and counts.

Abbreviations

PCD: external opening of the pharyngocutaneous duct; ordinarily confluent with the posteriormost left gill aperture, and much larger than all other apertures.

GA: gill (branchial) aperture; external opening of the efferent duct leading from a gill pouch.

GP: gill pouch; rounded, serially arranged structures along and posterior to the dental muscle.

DM: dental muscle; the firm, elongate, cylindrical complex of muscles and cartilages that moves the dental plates and sets of cusps during feeding. Posterior portions of DM are shown in Figure 3.

VA: ventral aorta; the portion between the heart (ventricle) and where it branches to each side of DM.

ABA: afferent branchial artery; one of the small blood vessels that lead to each gill pouch from VA or its branches.

Measurements

If the specimen is distorted due to preservation, it should be moderately straightened to approximate its normal form. Measurements are taken from the left side with the fish lying on a meter stick; dividers or dial calipers are advisable for shorter lengths. We arbitrarily divided the body into four major sections (Fig. 1): prebranchical, branchial, trunk, and caudal. These are particularly apropos to genera *Eptatretus* and *Paramyxine,* as each has more than one GA, thus a branchial section. In *Myxine, Neomyxine,* and *Nemamyxine,* there is only one GA on each side, that on the left being confluent with PCD.

Synonymous terms appearing in the literature are: "head" or "pectoral" for prebranchial, "gill" for branchial, and "abdominal" for trunk. The term "mucus" has often been used for slime, "teeth" for cusps, "tongue" or "lingual muscle" for dental muscle, and "outer" and "inner" for posterior and anterior in referring to the series of cusps.

Body measurements we have found particularly useful are:

Total length (TL): snout (anterior tip of rostrum, excluding barbels) to posteriormost margin of tail or caudal fin.

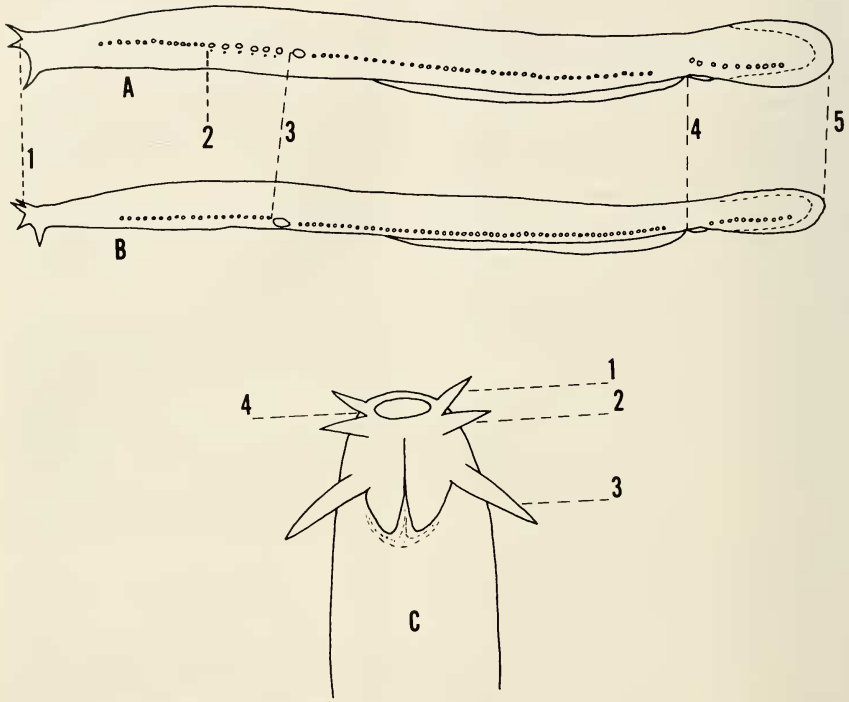


FIGURE 1. A–B: Sketches of an *Eptatretus* and a *Myxine*, showing regions of body used in study of myxinids: 1 to 5, total length; 1 to 2, prebranchial; 2 to 3, branchial; 3 to 4, trunk; 4 to 5, caudal. C: sketch of head region of a myxinid, showing barbel pairs 1, 2, and 3, and nasopharyngeal opening, 4.

Preocular length: snout to center of eyespot, unpigmented area (if present) marking the ocular region.

Prebranchial length: snout to front of first, or only, GA.

Branchial length: front of first to front of last GA (PCD). The anterior edge of the last GA is used because the posterior margin is often too vague and poorly defined to provide a definite reference point.

Trunk length: front of PCD to origin of cloaca.

Body width: maximum dimension about midway between rostrum and PCD.

Body depth: maximum vertical depth in trunk region, including finfold if present; depth excluding finfold should be taken at the same place. In both width and depth measurements the body should be molded into a seemingly natural shape if necessary.

Depth at cloaca: vertical depth at origin of cloaca.

Tail depth: maximum vertical depth of flattened tail, with any roll-up or fold of the thin tail margin uncurled and flattened.

Barbel length: from center of base to tip of each barbel (Fig. 1). The distance between bases of each pair may be measured from the inside edge of each base. Barbels are often curled and difficult to measure accurately, but in certain species barbel length may be a significant character, and is worth measuring.

Dental muscle length (DM): snout to tip of DM, as revealed by a midventral incision in the prebranchial region.

Dental muscle width: measured at a straight-sided portion well anterior to tapering end.

Dental muscle depth: measured at same place as width measure. Rather than using the total

length, we have found it convenient to compare the length (or width) with the unbranched portion of the VA with measurements of the DM. This is a significant ratio in certain species, but varies greatly between specimens of other species.

Weight: may be taken, but we have not found it to be a reliable or useful character, principally because of the uncertainty in determining if all the entrapped fluid was drained, and because of dehydration of body fluids during preservation.

Counts

Ordinarily the branchial openings (GA) are the first items examined to ascertain the genus and possible species. The gill pouches are usually counted after the teeth (cusps) when the oral cavity incision is extended midventrally to the region of the PCD. Before counting the slime pores, we gently scraped away any coagulated slime overlying the line of pores; an air jet greatly facilitated location of pores. Because so few specimens were available for this study, both sides were counted to obtain wider range of variation. Counts we have found particularly useful are:

Slime pores:

Prebranchial—from anteriormost slime pore to last one before first GA.

Branchial—those pores in immediate association with (usually below and to the right of) each GA; often one less than GA count in *Eptatretus,* and much less, or absent entirely, in *Paramyxine.* There is usually no slime pore associated with PCD, but this varies with species and individual specimens. In this study all species except *E. strahani* have a branchial pore count equal to or higher than the number of GA; the extra pores vary in location and number.

Trunk—the series posterior to PCD and terminating anterior to end of cloaca, distinctly separate from cloacal series.

Cloacal—the pores distinctly before a vertical from posterior end of cloaca, usually starting somewhat anterior to and elevated from origin of cloaca.

Caudal—from first pore distinctly behind a vertical from posterior end of cloaca to last pore on tail. For statistical purposes we combine counts of cloacal and caudal pores under the heading "tail pores" (Table 2).

Cusps (teeth): We refer to a single "tooth" as a cusp, or unicusp, if it is not fused to one or more adjoining cusps. A unit of two or more cusps fused together at some point prior to its embedment in the cartilaginous dental plate is a multicusp.

FIGURE 2. Cusps and basal plates, in excised and spread condition, of *E. carlhubbsi,* paratype USNM 233742, 955 mm TL.

The two paired sets of cusps (the outer and inner rows of Fernholm and Hubbs [1981] and Fernholm [1982]) are examined from the ventral aspect. They are revealed by a midline incision from the base of the oral cavity through the cartilaginous pharynx until the sets are free and easily turned outward for viewing. There are disadvantages to this method. It is easy to misjudge the midline (if the "face" has been distorted in preservation) and cut through the median teeth, making counts difficult; also, the resulting view presented to the observer is a reversed image of the actual arrangement. The inner left row appears on the outer right side and vice versa. To avoid this confusion, the incision may be made from either side of the oral cavity to just under the third barbel, then extended laterally downward through the thin membrane, exposing the paired sets of cusps which, when spread apart, appear as shown in Figure 2.

On most specimens the count of multicusps may be determined by placing a dissecting or air jet needle under the first two cusps and gently

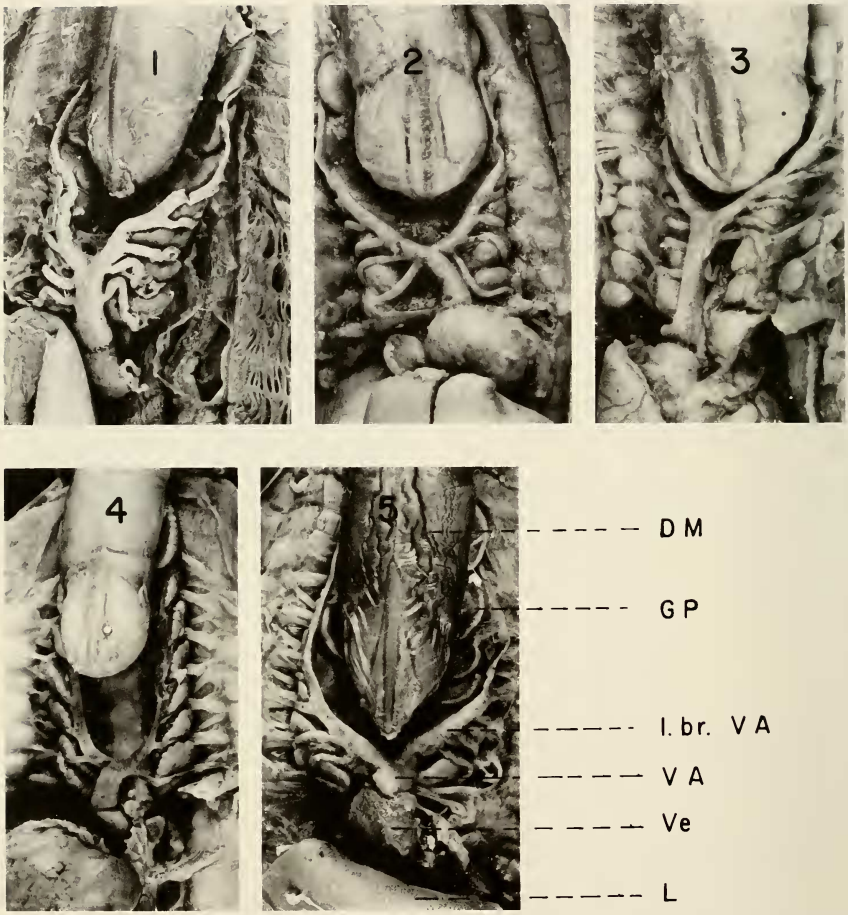


FIGURE 3. Ventral view of branchial region of: 1, *E. carlhubbsi*: 2–3, *E. laurahubbsi*, showing diversity in afferent branchial arteries (ABA) leading off from branches of ventral aorta (VA); 4, *E. strahani*; 5, *E. cirrhatus*.

lifting; the multicusp usually lifts and separates from the adjacent unfused cusp. However, in the nine largest specimens examined by us (*E. carlhubbsi*), lifting often raised the entire dental plate and set of cusps. Even if cusps are unquestionably fused, a line may extend among the fusion to the plate or "gum line;" in such instances perhaps the only valid criterion for separating multicusps from unicusps is the distinctness of this line as seen under magnification. Such lines are in marked contrast to the condition shown by scanning electron microscopy of *E. springeri* (Fernholm and Hubbs 1981: fig. 2), wherein no lines are evident in the multicusps.

Gill apertures and pouches: In genera *Myxine, Neomyxine, Nemamyxine,* and *Notomyxine,* dissection is necessary to determine the number of gill pouches, since only one pair of efferent ducts leads to the exterior. A midventral incision is made from the single pair of GA anteriorly

until all pouches are revealed (Fig. 3). The cut should be deep enough to expose VA and ventricle, taking care not to sever branches of VA or any ABA, or to destroy the origin of the ventral finfold if it is present anterior to PCD.

There are multiple, readily visible GA in genera *Eptatretus* (5–15 pairs) and *Paramyxine* (5–7 pairs). Although the number of internal pouches ordinarily is the same as the external apertures, there may be variation; thus, it is desirable to count the pouches and examine the arrangement of the GP relative to DM and branched and unbranched portions of VA (Fig. 3). The arrangement is often of taxonomic importance, although variation occurs (see *E. laurahubbsi*).

Sensory canals (lateral lines): Ayers and Worthington (1907:331, figs. 5–10), in a study of the skin-end organs of the trigeminal and lateralis nerves of *Bdellostoma dombeyi* (=*Eptatretus stoutii* [Lockington 1878]), described and figured lateral line canals, associated dermal grooves, and nerve endings. They showed the canals as short lines occurring only dorsally and somewhat laterally on the "head" and in two groups, one before and one behind the eyespots. Plate (1924: 66, fig. 61D) accepted the interpretation by Ayers and Worthington that the short lines constituted lateral line canals, but considered the dermal grooves to be artifacts. Ross (1963:155) cited both these studies and stated that the lateral lines had not been described in *Myxine glutinosa*. To our knowledge these are the only prior references to lateral line canals of hagfishes.

We concur with Ayers and Worthington that the canals occur only on the head (in the ocular area of the prebranchial region). However, they are lateral only in that a few occur on the side of the head, with most on the dorsal surface (Fig. 4), and none at all on the rest of the body. Assuming that the canals are indeed sensory in function, we prefer the term "sensory" to "lateral." Sensory canals occur in only two of the four species discussed here (*E. strahani* and *E. cirrhatus,* Fig. 4), but not on all specimens, and are irregular in number and form. The erratic occurrence in location and in numbers of canals is intriguing, as is their total absence in two of the four species.

Due to the limited number of specimens available, it is difficult to draw any firm conclusions regarding the taxonomic value of sensory canals. Ayers and Worthington (1907) stated that these canals were difficult to find because they were

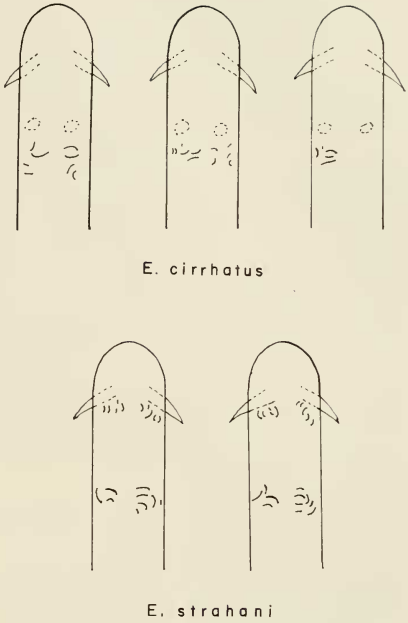


FIGURE 4. Sketches (not to scale) of head regions of *Eptatretus cirrhatus* and *E. strahani* showing arrangements of sensory canals. The first two pairs of barbels are omitted.

very small and the surface indications faint, and that any apparent erratic appearance might be due to the observer. However, on the specimens examined by us the canals, when present, were readily visible under adequate magnification and lighting, and often by the unaided eye. They appear as thin lines, about 1–3 mm long, variably straight or curved (Fig. 4), often very slightly raised above the skin, and sometimes covered with a coating of coagulated slime. Histological examination was not done, nor have we attempted to observe these canals on unpreserved fishes.

Old, healed scars are often present in areas occupied by the sensory canals, and elsewhere on the body, mostly anteriorly. These are identifiable as shallow depressions, usually wider and longer than the sensory canals. Many scars occur singly, but often they are in groups of parallel lines, the spacing closely resembling that of the anterior cusps. Possibly this scarring occurs when many hagfishes are feeding in close proximity competing for food, or when crowded in a trap.

Table 1. Averages and Ranges (in Thousandths of Total Length) of Selected Body Proportions for Four Species of Seven-gilled Hagfishes (Genus *Eptatretus*) from the Pacific Ocean.

	E. carlhubbsi	*E. laurahubbsi*	*E. strahani*	*E. cirrhatus*
N (size range in mm)	9 (813–1160)	8 (240–375)	5 (265–520)	8 (481–655)
	Avg. (range)	Avg. (range)	Avg. (range)	Avg. (range)
Preocular length	38 (36–54)	50 (44–59)	63 (57–68)*	60 (52–67)
Prebranchial length	184 (168–197)	193 (184–204)	220 (210–231)	225 (214–239)
Branchial length	68 (55–77)	55 (52–59)	77 (69–83)	76 (69–89)
Trunk length	602 (577–623)	561 (545–585)	521 (500–537)	550 (525–563)
Tail length	160 (145–176)	198 (181–213)	182 (174–202)	154 (135–168)
Tail depth	97 (89–105)	90 (82–99)	117 (109–125)	83 (77–91)
Body depth with finfold	No finfold	89 (74–97)	111 (101–117)	89 (69–102)
Body depth without finfold	93 (78–106)	81 (73–91)	98 (94–105)	88 (69–102)
Body depth at cloaca	73 (65–85)	70 (61–80)	87 (77–94)	67 (57–75)

* Due to lack of visible eyespots, the preocular length was taken from center of uncovered pupil.

Waite (1909) placed three adult *E. cirrhatus* in a bucket of formalin and observed them savagely attacking each other. One was bitten at least 15 times by the other two.

Key to Seven-gilled Species of *Eptatretus* from the Pacific Ocean

1a. Slime pores of trunk 60–70, low, well below mid-lateral aspect. Total cusps 61–71. Eyespots present 2

1b. Slime pores of trunk 45–53, high, near mid-lateral aspect. Total cusps 43–53. Eyespots present or absent 3

2a. Ventral finfold absent. Two (rarely three) fused cusps on anterior multicusps, three on the posterior. Eyespots large, prominent ..... *E. carlhubbsi* n.sp.

2b. Ventral finfold prominent. Two (rarely three) fused cusps on each of the four multicusps. Eyespots present ..... *E. laurahubbsi* n.sp.

3a. Ventral finfold readily visible. Eyespots absent. Ventral margin of tail forming a nearly straight line from cloaca to abrupt beginning of curve around tail. Anterior few gill apertures small, slitlike. No pale rings around slime pores or gill apertures. Three fused cusps on each of the four multicusps ..... *E. strahani* n.sp.

3b. Ventral finfold vestigial. Eyespots present. Tail margin smoothly ovate. All apertures rounded. Pale rings around slime pores and gill apertures. Three fused cusps on each of the multicusps ..... *E. cirrhatus*

Eptatretus carlhubbsi new species

Holotype.—SIO 68-473, mature female, 961 mm TL, taken at 19°18'N, 166°33.5'E, near Wake Island, in a free-vehicle trap on bottom at 1574 m, 12–13 Sept. 1968.

Paratypes.—SIO 68-473, female, 810 mm TL, taken with the holotype; SIO 82-63 (formerly BPBM 27850), female, 1125 mm TL, taken at Brooks Banks, between French Frigate Shoals and Gardner Pinnacles, Leeward Islands, Hawaii, Nov. 1981, *Mokihana* Cruise 81-12, set 35, shrimp trap, depth not given; BPBM 27848, male, 1160 mm TL, taken at 12°56'N, 166°22'W, French Frigate Shoals, Leeward Islands, Hawaii, 7 Nov. 1981, shrimp trap at 684 m; BPBM 27851, male, 830 mm TL, taken off the north shore of Molokai Island, Hawaii, 26–27 Dec. 1981, shrimp trap at 659 m; USNM 227440, male, 900 mm TL, taken at 24°48'N, 167°14'W, R/V *Cromwell* Cruise 80-05, Station 57, in a shrimp trap at 835 m; USNM 233742 (formerly NMFS P-0289), male, 955 mm TL, taken at 14°59'N, 145°13'E, Esmeralda Bank, Guam, 5–6 April 1981, Cruise *Typhoon* 81-01, Station 151, in a shrimp trap at 1061 m; CAS 50705 (formerly BPBM 27847), male, 1064 mm TL, Leeward Islands, Hawaii, Nov.–Dec. 1981, depth and method of capture not given; CAS 50706 (formerly BPBM 27849), male, 980 mm TL, taken at French Frigate Shoals, East Plateau, north side, Leeward Islands, Hawaii, 19 Nov. 1981, in a shrimp trap at 481 m.

Diagnosis.—A seven-gilled *Eptatretus* having no ventral finfold, very large eyespots, two (rarely three) fused cusps on the anterior multicusps and three on the posterior.

Description.—Counts: Those of holotype given first (left and right sides), followed by ranges for all specimens in parentheses: gill apertures 7, 7 (all); prebranchial slime pores 15, 16 (12–17); branchial pores 7, 7 (6–8); trunk pores 60, 61 (60–70); cloacal pores 2, 2 (1–3); caudal pores 11, 11 (11–13); tail pores 13, 13 (12–16); total slime pores 95, 97 (93–110). Cusps on anterior multicusps 2, 2 (rarely 3); posterior multicusps 3, 3 (all); anterior unicusps 16, 16 (15–17); pos-

TABLE 2. PREBRANCHIAL, BRANCHIAL, AND TAIL SLIME PORES OF FOUR SPECIES OF SEVEN-GILLED HAGFISHES (GENUS *EPTATRETUS*) FROM THE PACIFIC OCEAN.

	Prebranchial slime pores									
	12	13	14	15	16	17	18	19	20	N
E. carlhubbsi	1	7	2	5	2	1				18
E. laurahubbsi			2	3	8	3				16
E. strahani		1	4	2	3					10
E. cirrhatus					4	17	17	4	1	43

	Branchial slime pores			
	6	7	8	N
E. carlhubbsi	4	12	2	18
E. laurahubbsi	7	6	3	16
E. strahani	10			10
E. cirrhatus	7	34	2	43

	Tail slime pores[1]							
	10	11	12	13	14	15	16	N
E. carlhubbsi			2	4	3	8	1	18
E. laurahubbsi					2	12	2	16
E. strahani	3	4	2					9
E. cirrhatus	1	6	16	14	6			43

[1] Tail count is the total of the cloacal and caudal slime pores.

terior unicusps 12, 13 (11–13); total cusps 68 (64–71).

Morphometry: In thousandths of total length; values for holotype given first, followed by ranges for all specimens: preocular length 38 (36–54); prebranchial length 184 (168–197); branchial length 68 (55–77); trunk length 602 (577–623); tail length 160 (145–176); tail depth 97 (89–105); body depth 90 (78–112); depth at cloaca 74 (62–86).

All specimens from Hawaii were frozen initially; the body proportions of these may not be closely comparable to the other collections, which were initially preserved in formalin. It is not known what effect freezing may have on subsequent shrinkage, but it is possible that the soft tissues of hagfishes are greatly affected by the expansion of cells in freezing. It is known that length of time in preservative significantly affects the total length; a shrinkage of 10% is not uncommon. However, to our knowledge no study has been done showing the changes in other body proportions. Body proportions (Table 1) and counts (Tables 2–6) are compared with similar data for other seven-gilled *Eptatretus* from the Pacific Ocean.

Body robust; prebranchial region slightly deeper than wide; body increasingly compressed laterally to tail, varying in greatest depth from 8% to 11% of TL. Two to four GP anterior to tip of DM, which is somewhat flattened posteriorly. Length of DM 19% (17–21%) of TL, its width 15% (9–19%) of its length, its depth 66% (57–87%) of its width. VA short, wide, its width

TABLE 3. TRUNK SLIME PORES OF FOUR SPECIES OF SEVEN-GILLED HAGFISHES (GENUS *EPTATRETUS*) FROM THE PACIFIC OCEAN.

	Trunk slime pores																													
	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	N
E. carlhubbsi																1	2			3		1	4	5		2	18
E. laurahubbsi																3	1	2	2		1	2	5				16
E. strahani	2	2	2	3																							9
E. cirrhatus		5	2	10	11	3	5	2	5																		43

TABLE 4. TOTAL SLIME PORES OF FOUR SPECIES OF SEVEN-GILLED HAGFISHES (GENUS *EPTATRETUS*) FROM THE PACIFIC OCEAN.

	Total pores																																						
	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	N
E. carlhubbsi																		1		1		2			3	1	2		2	4		1			1	18
E. laurahubbsi																						2		1	3	3		3	2	2						16
E. strahani		2	1	1	2	3																														9
E. cirrhatus								4	7	7	8	5	5	4	3																					43

39% (35–43%) of its length. Distance between DM and branching of VA 17% (12–22%) of DM length. GA rather evenly spaced in a line often sloping or curving slightly downward posteriorly, with the exception of paratype BPBM 27851, apparently an aberrant specimen. It has eight GP on each side, but with corresponding apertures arranged abnormally (Fig. 6); there are eight GA on the left side, but only seven on the right, with two gills sharing one aperture.

Head blunt, face sloping at about 30° from the vertical. Eyespots large, prominent, ranging from nearly round to square or rectangular. Removal of overlying integument shows the embedded eyes varying from under to well behind center of eyespots. Eyes nearly round, about 5 by 6 mm, slanting ventrodorsally at about 45°. The first two pairs of barbels of nearly equal length on the holotype, the second pair slightly shorter than the first. Proportions of the barbel pairs on the paratypes show great variation, with some of the first pairs shorter than the second. The second barbel, right side, of paratype SIO 68–473 is bifurcate to the base, both halves of about equal length. No sensory canals are present on any of the specimens.

There is no ventral finfold, but an intermittent, vague line resembling a median suture extends from well behind PCD nearly to cloaca. The thin margin of the tail, common on other hagfishes, is not readily evident in these large specimens. If a caudal finfold is present, it is very thick, tapering steeply from the tail musculature. This may be a species character or merely the result of age or size; no juveniles are known. In the other three species discussed below (particularly the juvenile specimens of *E. laurahubbsi*) the tail margins are notably deeper and thinner. The average tail length in the nine specimens of *E. carlhubbsi* is about twice (1.9–2.5) the body depth at the origin of the cloaca, but the shapes of the tails vary considerably (Fig. 5). The deep notch on the dorsal surface of the tail of the holotype is apparently an old, entirely healed injury; no notch is present on any paratype. The tail depths average 58% (49–65%) of the lengths; shape varies from that of a truncated club (No. 7) with no evidence of finfolds to the very deep, expanded form of No. 3, which has a notably less thickened margin.

The holotype and three paratypes are tan in color; two are from Wake Island, and one each

TABLE 5. UNICUSPS IN THE ANTERIOR AND POSTERIOR SETS OF CUSPS OF FOUR SPECIES OF SEVEN-GILLED HAGFISHES (GENUS *EPTATRETUS*) FROM THE PACIFIC OCEAN.

	Anterior unicusps										
	8	9	10	11	12	13	14	15	16	17	N
E. carlhubbsi								5	10	3	18
E. laurahubbsi						1	1	4	7	3	16
E. strahani		2	4	4							10
E. cirrhatus	7	28	7	1							43

	Posterior unicusps										
	7	8	9	10	11	12	13	14	15	16	N
E. carlhubbsi					3	8	7				18
E. laurahubbsi					1	10	4			1	16
E. strahani		2	5	3							10
E. cirrhatus	2	26	15								43

from French Frigate Shoals and Molokai, Hawaii. Five paratypes (one from Guam, four from Leeward Islands, Hawaii) are a purplish brown; the Guam specimen has a more brownish overtone. Scattered, irregularly shaped pale areas of varying sizes occur mainly on the anterior portions of the body and occasionally as small patches on the other parts; these light spots are more visible on the purplish-brown specimens. Small, very dark brown blotches occur randomly on all but one of the tan specimens. Pale rings surround the GA, but not the slime pores. The color differences are striking, but such variation is known in other species wherein blotching, lighter shades, and even albinism occur (Dean 1903; Jensen 1959).

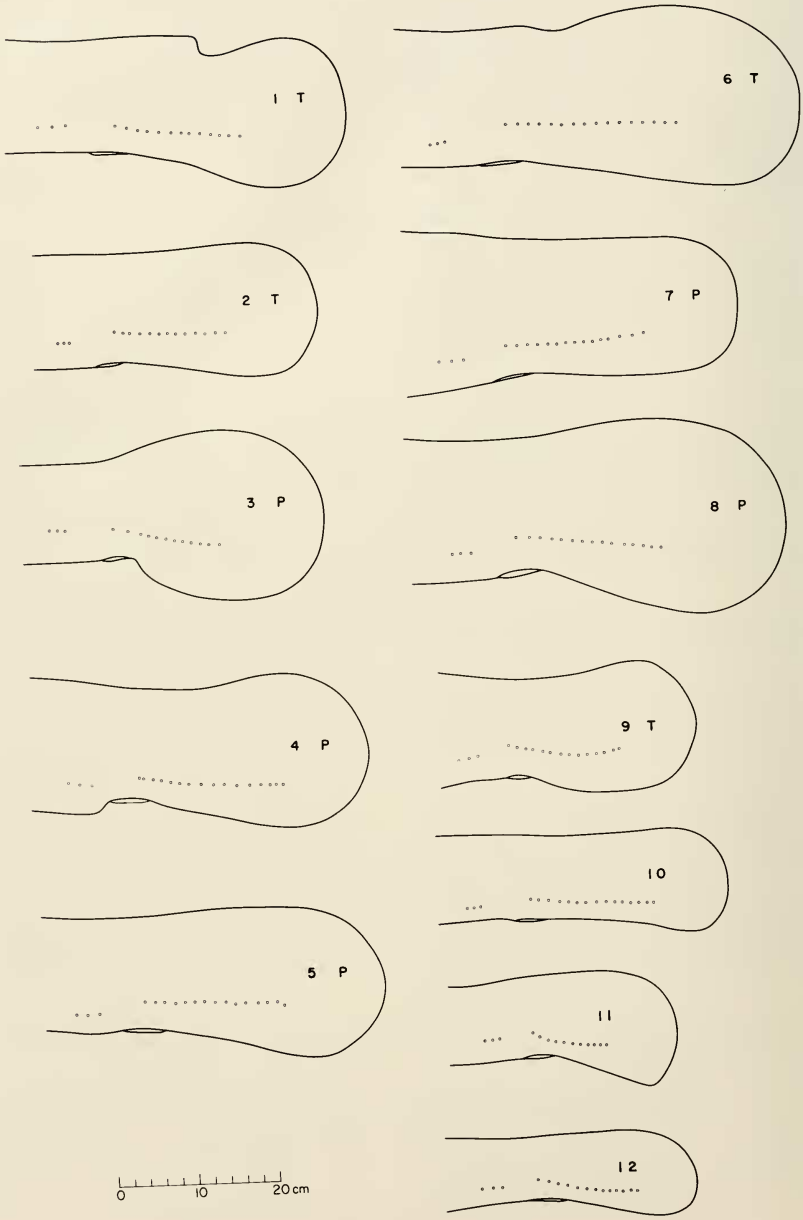
The color variations discussed above and the striking differences in tail shapes and barbel ratios, as well as wide ranges in other body proportions and differences, often indicate the presence of more than one species, but we find no definite correlation between these characters and those of counts, sex, other body proportions, or geographical areas. Further collections may show that subspecies or other taxa occur within or between the three areas—Hawaii, Wake Island, and Guam.

The first few prebranchial pores curve gently downward on the holotype, but on all paratypes they are in an essentially straight line (occasionally the first one or two are slightly depressed). There are seven or eight slime pores in the branchial region, one or two more than expected, which is one less than the number of GA.

Eggs: The holotype contained at least 21 eggs, the largest 58.5 by 14.4 mm. These eggs had been removed and bottled separately by an earlier investigator, and it is not known that all were preserved. None were in the specimen when examined by us. Paratype BPBM 27848 contained 32 eggs, the largest 75.5 by 16.5 mm. Some eggs were damaged by freezing, the original preservative, and were loose in the body; these are now bottled separately. Eight eggs, the largest 58.5 by 14.4 mm, were packaged separately within a larger pack containing a male and a female (SIO 82-63, formerly BPBM 27850). The female contained only 13 eggs, the largest 63.0 by 12.6 mm.

TABLE 6. TOTAL CUSPS OF FOUR SPECIES OF SEVEN-GILLED HAGFISHES (GENUS *EPTATRETUS*) FROM THE PACIFIC OCEAN.

	Total cusps																														
	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	N
E. carlhubbsi																					1	2	1		2	1	1		1	9
E. laurahubbsi																			2		1		4			1				8
E. strahani					1			1		3																				5
E. cirrhatus	1	2	2	8	2	3	1	2	1																					22


1 T
2 T
3 P
4 P
5 P
6 T
7 P
8 P
9 T
10
11
12
0
10
20 cm

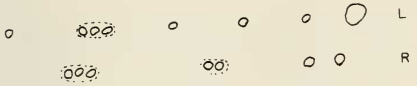


FIGURE 6. Sketch of abberrant arrangement of gill apertures of a specimen of *E. carlhubbsi*, paratype BPBM 27851, 830 mm TL.

Although there was no identifying label with the separate eggs, we assume they had been taken from the same female. Since the Hawaiian specimens apparently were all frozen as initial preservative, these eggs could have been stripped prior to immersion in preservative; the specimen had not been cut open anywhere on the body. Although all were extremely large, none of the eggs cited above had the terminal hooks of fully ripe eggs (Dean 1899; Jespersen 1975).

ETYMOLOGY.—With great respect and admiration we dedicate this species of giant hagfish to the late Carl L. Hubbs, himself a giant in ichthyology.

Eptatretus laurahubbsi new species

HOLOTYPE.—SIO 65-643, juvenile female, 375 mm TL, taken at 33°31'S, 78°50'W, near Más a Tierra, Islas Juan Fernández, in a free vehicle trap on bottom at 2400 meters, between hours of 2030 and 0830, 12–13 Dec. 1965, Cruise 12 of R/V *Anton Bruun*.

PARATYPES (remaining material examined).—Seven juveniles (sex questionable) taken with the holotype, are deposited as follows: SIO 65-643, two, 369 and 287 mm TL (deposited with the holotype); CAS 49125, two, 287 and 358 mm TL; USNM 227441, two, 240 and 265 mm TL, Museo Nacionál de Chile, Santiago, one, 240 mm TL.

DIAGNOSIS.—A seven-gilled *Eptatretus* having a well-developed finfold and only two (rarely three) fused cusps on each of the four multicusps.

DESCRIPTION.—Counts: Those of the holotype given first (left and right sides), followed by ranges for all specimens in parentheses: gill apertures 7, 7 (all); prebranchial slime pores 17, 16 (14–17); branchial pores 7, 7 (6–8); trunk pores 67, 66 (60–67); cloacal pores 2, 3 (2–3); caudal pores 12, 12 (11–14); tail pores 14, 15 (14–16); total slime pores 105, 104 (97–105). Cusps on anterior multicusps 2, 2 (2, 3); posterior multicusps 2, 2 (2–3); anterior unicusps 15, 16 (13, 17); posterior unicusps 12, 12 (11–16); total cusps 63 (61–68).

Morphometry: Values in thousandths of TL given first for the holotype, followed by ranges for all specimens (left side): preocular length 53 (52–59); trunk length 560 (545–585); tail length 189 (181–213); maximum body depth including finfold 89 (74–97), excluding finfold 84 (73–91); body depth at cloaca 69 (61–80); tail depth 82 (82–89). Morphometric data (Table 1) and counts (Tables 2–6) are compared with similar data for other seven-gilled *Eptatretus* from the Pacific Ocean.

Body deeper than wide, width at midbody about 1.6 in depth. Tail broadly ovate, its depth slightly greater than body depth. Ventral finfold well developed, originating well behind PCD; a broad, thin finfold from posterior margin of cloaca around tail and dorsally until about over anterior margin of cloaca (Fig. 5–1). Dorsal profile of head sloping to a very blunt, nearly straight-across rostrum; width of nasopharyngeal orifice about equal to length of third barbels. First pair of barbels about 63% of length of third pair; second pair about 75%.

Color notes were not taken at time of capture (December 1965); all specimens are now a uniform yellowish color, no doubt a result of fading. The eyespots are no longer discernible, but preocular measurements were recorded by the senior author in November 1973. Removal of integument over the right eye of a 287-mm specimen shows the eye to be round, about 2.5 mm in diameter, with a small triangular pupil with its base dorsad and slanting forward at a slight angle to horizontal axis of body. No sensory canals are evident on any specimen.

Despite the faded condition of all specimens, the branchial apertures and most slime pores have whitish borders. Usually one pore, plus an occasional extra one, occurs adjacent to each BA. Two pores are near the opening of PCD on four specimens; three have one pore, and one has none near PCD (as is the usual condition on other

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FIGURE 5. Tail shapes (to scale) and patterns of occurrence of the last four trunk pores and cloacal and tail slime pores of four species of seven-gilled *Eptatretus* from the Pacific Ocean: 1–9 *E. carlhubbsii* (T = tan color, P = purplish color); 1—Holotype, SIO 68-473, 961 mm TL; 2–9 Paratypes: 2—SIO 68-473, 813 mm TL; 3—USNM 227440, 900 mm TL; 4—USNM 233742, 955 mm TL; 5—CAS 50705, 1064 mm TL; 6—BPBM 27848, 1160 mm TL; 7—CAS 50706, 908 mm TL; 8—SIO 82-63, 1125 mm TL; 9—BPBM 27851, 830 mm TL; 10—Holotype, *E. laurahubbsi*, SIO 65–643, 375 mm TL; 11—Holotype, *E. strahani*, MNHN 1978-462, 520 mm TL; 12—*E. cirrhatus*, 655 mm TL.

Eptatretus). Space between the last trunk pore and first cloacal pore is about equal to length of cloaca (Fig. 1). Two or three slime pores lie over cloaca in a straight line and equally spaced with caudal pores. Prebranchial pores in a fairly straight line; occasionally the first one to three slightly depressed.

There is great variation in the arrangement of GP and afferent branchial arteries (ABA) with respect to the DM and branching of VA (Figs. 3-2 and 3-3). The number of GP along DM are far more variable than in the other three species, ranging from two to five. Also, length of VA varies notably; in six specimens VA averages 8.1% (6.3–9.3%) of length of DM, but in one 240-mm specimen the length of VA was 14.4% of DM, with three ABA leading off the left side and two off the right. This variation is in marked contrast to the regular arrangement of the branchial apparatus of the three other species discussed herein.

The eight specimens of *E. laurahubbsi* are unusual within genus *Eptatretus* in the appearance of the multicusps, apparently having only two fused cusps in each series. Indeed, it is often a highly subjective decision as to whether any of the anteriormost cusps are fused as multicusps. One specimen appears to have three fused cusps in each of the anterior series and two in the posterior series. In two specimens it is questionable as to whether two or three cusps are fused in the posterior rows. In other *Eptatretus* known from the southern hemisphere the usual configuration is three fused cusps on each of the four multicusps; all *Eptatretus* known from the North American Pacific coast have three in the anterior and two in the posterior row, which are distinct and clearly seen even in juveniles. A juvenile (188 mm) *E. stoutii* (Lockington 1878) clearly shows hard, well-developed cusps with the pattern 3/2. Also, a 100-mm specimen of *E. polytrema* (Girard 1855) from Chile has three distinctly fused cusps in each multicusp; adults of this species attain a total length of at least 550 mm. Thus, the presence of only two fused cusps in most specimens of *E. laurahubbsi,* and the uncertainty regarding the number fused in the others, is apparently not due to immaturity or small size.

All of our study specimens are juveniles, but it is highly probable that adults exceed one meter in length. The longest (holotype), although 373 mm TL, contains minute eggs, seen with difficulty under magnification. In another *Eptatretus* (undescribed) from the Gulf of California, a specimen of this size may have fully developed gonads and large eggs. Gumersindo Revuelta, a former student at the University of Chile, Valparaíso, in an unpublished thesis (1976), sketched and gave limited data on a very large hagfish, slightly exceeding a meter in length (from scale provided with sketch). He tentatively identified it with the giant *Eptatretus* taken at Wake Island (from data sent to him by Hubbs), probably because of its gigantic size compared to other species from Chilean waters. Revuelta had at least two females, both apparently very large, for he sent to Hubbs (in 1976) two large eggs: one 68 by 16.5 mm from Valparaíso, and one 72 by 16.8 mm from "Juan Fernandez" (presumably the island). We presume these large specimens to be adults of *E. laurahubbsi* because Revuelta reported the multicusps as 2/2, and his limited data are in close agreement to those of our specimens taken in the same vicinity. Also, in *E. carlhubbsi* the ventral finfold is entirely absent, but Revuelta's sketch shows a ventral finfold originating a little behind the anterior third of the body. In our juveniles a pronounced finfold originates variably between the midpoint and anterior third of the body; the exact point of origin is indeterminate because of wrinkling during preservation.

Etymology.—We dedicate this unique species to our friend and and co-worker, Laura Clark Hubbs, who contributed in so many ways to the life and works of her husband, Carl Leavitt Hubbs.

Eptatretus strahani new species

Holotype.—MNHN 1978-462, female, 520 mm TL, containing eggs of about 4.5 mm in length, taken at 14°00'N, 120°18'.2"E, South China Sea near Lubang Island, Philippines, in a trap net at 189 meters, Station 22 *Musorstom* Expedition, 21–22 March 1976, 1800–0600 hours.

Paratypes (and remaining material examined; all taken with the holotype).—MNHN 1981-722, female, 420 mm TL; SIO 81-116, female, 265 mm TL, male, 450 mm TL; USNM 227442, male, 465 mm TL.

Additional Material.—UPZM 1981-809, 400 mm TL; UPZM 1981-811, 480 mm TL. Total lengths, comparisons, and identifications were made by Prof. Reynaldo de La Paz, University of the Philippines, Diliman, Quezon City, Philippines, based on methods and data provided by us.

Diagnosis.—A seven-gilled *Eptatretus* having no eyespots, a well-developed ventral finfold, and three fused cusps on each of the four multicusps.

Description.—Counts: Those of the holotype given first, followed by ranges in parentheses for

all five specimens (both sides counted): gill apertures 7, 7 (all); prebranchial slime pores 14, 16 (13–16); branchial pores 6, 6 (6–7); trunk pores 45, 47 (45–48); cloacal pores 4, 3 (3–4); caudal pores 7, 7 (6–8); total tail pores 11, 11 (10–12); total slime pores 76, 79 (76–80). Cusps on multicusps 3, 3 (all); anterior unicusps 11, 11 (9–11); posterior unicusps 9, 9 (8–10); total cusps 52 (47–52).

Morphometry: Values for holotype given first, followed by ranges for all five specimens, in thousandths of total length: preocular length (no eyespots); prebranchial length 231 (210–231); branchial length 81 (69–83); trunk length 500 (500–537); tail length 196 (174–202); body depth including finfold 115 (101–117); excluding finfold 95 (94–105); body depth over anterior margin of cloaca 88 (77–94); tail depth 119 (109–125). Morphometry (Table 1) and counts (Tables 2–6) are compared with similar data for other seven-gilled *Eptatretus* from the Pacific Ocean.

Body deeper than wide, deepest at midsection. Ventral finfold well developed, extending from about midbody to cloaca, its length about 31% of TL. Tail margin quite thin posterior to cloaca, extending around tail to dorsal surface, ending at about a vertical from posterior end of cloaca. Ventral outline of tail forms a nearly straight line, ending with an abrupt curvature up and around end to dorsal aspect. This shape is in marked contrast to the gradual curvature of tails of the other three species treated herein (Fig. 5).

Dorsal profile of head sloping steeply to snout; rostrum more rounded than in *E. carlhubbsi* or *E. laurahubbsi*; width of nasopharyngeal opening about 60–80% of length of first pair of barbels. First two pairs of barbels nearly equal in length; respectively, about 66% and 72% of length of third pair. First barbel, left side, of a 420-mm female is bifurcate to near base, with posterior branch shorter. Since we have occasionally seen this bifurcation in other hagfishes (usually near the tip, and always on only one barbel of the six), we assume this form is the result of an injury rather than some genetic malformation.

No eyespots are visible on any specimen (about 30 months after capture). Since the body color is still fairly dark we have assumed that little or no fading has occurred, and that the unpigmented eyespot area should still be visible if present in life. No notes regarding eyespots were made at time of capture. Removal of overlying integument on holotype shows eye to be ovate (3.4 by 2.4 mm) and slanted ventrodorsally at about a 45° angle; pupil more rounded (1.4 by 1.1 mm).

Sensory canals are present in two groups on each side of the head before and behind the area where eyespots normally occur (Fig. 4). One group of sensory canals is found near the bases of the third pair of barbels, anterior to embedded eyes, another group slightly posterior to eyes. Anterior group consists of five more-or-less longitudinal lines 1–3 mm long; canals of posterior group both longitudinally and horizontally arranged, those on top of head tending to be more horizontal. No canals extend across dorso-medial line.

Color of holotype (in preservative) a light brown, all paratypes a darker brown, the smallest the darkest. No discernible whitish rings around slime pores or GA on larger specimens, but the GA of the smallest one has distinctly pale margins. Finfold anterior to cloaca is same color as body, but tail has a very narrow, pale margin extending a short distance forward on the dorsal surface.

The line of the anterior prebranchial slime pores is straighter in this species than in the other three discussed; two specimens have only slight curvature, and no anterior pores are markedly elevated above adjacent ones in the prebranchial series. Space between last trunk and first cloacal pore about 65% of length of cloaca; spacing is variable with degree of slant or elevation of first cloacal pore (Fig. 5). Cloacal pores form a distinct dorsoventral slant on left side of holotype, but not on right; slanting is variable on paratypes.

Most GA are shaped as slits, slanting ventrodorsally; this shape could be an artifact of preservation, but the GA may be made to assume a rounded form only by considerable pulling and squeezing of surrounding flesh; all the slime pores below GA are rounded.

Three to five GP lie anterior to tip of DM (Fig. 3); two to four lie between that tip and branching of VA, and none posterior, although one GP of the smallest specimen (265 mm TL) lies just at the branching. Length of VA 6.4% (5.4–7.6%) of DM length; DM length 26% (25–27%) of TL, its width 15% (13–16%) of its length. Distance between tip of DM and branching of VA 9% (7.2–10.9%) of DM length.

ETYMOLOGY.—We are pleased to dedicate this new species to Ronald Strahan in acknowledgment of his important contributions to the study of Myxinidae.

Eptatretus cirrhatus (Bloch and Schneider, 1801)

Petromyzon cirrhatus Bloch and Schneider, 1801:532 (original description fide Forster ms II:24 [habits: New Zealand]).

Homea banksii Fleming, 1822:374 (South Seas [presumptive]).

Bdellostoma Forsteri Müller, 1834:71, 80 (anatomy; characters in key; reference to *Petromyzon cirrhatus* Bloch); Schneider, 1880:115 (status uncertain; based on a poor specimen).

Bdellostoma heptatrema Müller, 1834:7 (original description; New Zealand).

Bdellostoma cirrahatum Günther, 1870:511 (synonymy, in part; diagnosis, in part; distribution [New Zealand only]); Hutton, 1872:87 (characters; color reddish brown, white around mouth; common Australia and South Africa [misidentified with *E. heptatrema*]); Putnam, 1874:156 (in part; New Zealand; 7 gill slits); Schneider, 1880:115 (in part; doubts on status); Adam and Strahan, 1963:6 (6 or 7 pairs of gills; average length 480 mm; South Pacific, common off New Zealand).

Homea cirrhata Garman, 1899:341, 345, 349, 419 (synonymy; nomenclature); Dean, 1904:21 (in part; synonymy; New Zealand).

Heptatrema cirrata [sic] Hutton, 1904:55 (listed; New Zealand).

Eptatretus cirrahatus Berg, 1906:173 (in part; New Zealand); Waite, 1909:2 (description; behavior; average length 680 mm; Timaru and Chatham Islands; New Zealand); Graham, 1965:67 (plentiful on North Otago Shelf, New Zealand; often takes baited hooks); Heath and Moreland, 1967:30 (shore to 1800 ft; more abundant south of Hawke Bay than elsewhere in New Zealand); Whitley, 1968:4 (synonymy); Scott, Glover, and Southcott, 1974:19 (New Zealand, New South Wales, S.E. Australia); Fernholm, 1974:351 (in shallow water, New Zealand); Fernholm and Holmberg, 1975:253 (structure of eye, comparative; Kaikoura, S. Island, New Zealand); Strahan, 1975:145 (key; description; ranges of counts and body proportions).

Heptatretus banksii, Regan, 1912:534, 536 (comparisons; synonymy; diagnosis; D'Urville Is., Queen Charlotte Sound, New Zealand.).

Material Examined (counts and measurements both taken).—SIO 81-105, two males, 488 and 655 mm TL, three females 481–636 mm TL, 42°24′S, 173°41′E, no data on depth or date of capture, received from J. A. F. Garrick, Zoology Department, Victoria University of Wellington, New Zealand, 1 Nov. 1972; SIO 62-482-4A, two females, 577 and 580 mm TL, received from L. R. Richardson, Wellington, New Zealand, 25 March 1959, no data on depth of capture; ZIN 717-966, male, 595 mm TL, 40°19′S, 172°15′E, 160–172 meters, 18 Jan. 1965.

Counts only taken: AMS I 15527-001, three males, 254–452 mm TL, 26°32′S, 153°51′E, agassiz trawl, 175 fms (320 m), 27 July 1968; AMS Kapala Station 71-07-03, female, 505 mm TL, 33°33′–37′S, 152°01′–151°57′E, 205 fms (375 m), 21 April 1971; AMS Kapala Station 71-08-05, male, 265 mm TL, female, 552 mm TL, 33°11′S, 152°23′E, otter trawl, 310 fms (567 m), 29 April 1971; AMS Kapala Station 71-11-07, two females, 491, 514 mm TL, 34°40′–35°01′S, 151°10′–07′E, otter trawl, 300 fms (549 m), 7 July 1971; AMS Kapala Station 71-11-08, female, 410 mm TL, 34°56′–35°02′S, 151°06′–05′E, otter trawl, 160 fms (194 m), 8 July 1971; AMS Kapala Station 71-11-10, male, 447 mm TL, 35°11′–37′S, 150°45′–42′E, otter trawl, 230 fms (421 m), 8 July 1971; AMS Kapala Station 71-12-04, female, 546 mm TL, 33°41′–49′S, 151°53′–47′E, otter trawl, 245–250 fms (448–457 m), 20 July 1971; AMS Kapala Station 71-12A-06, three females, 374–503 mm TL, 35°25′–29′S, 150°50′–48′E, otter trawl, 300 fms (549 m), 2 Aug. 1971.

Diagnosis.—A seven-gilled *Eptatretus* having a vestigial ventral finfold, small but prominent eyespots, white around the mouth, pale rings around branchial apertures and slime pores; three fused cusps on each multicusp; sensory canals may occur.

Description.—Despite its being the first hagfish described from the Pacific Ocean, the literature contains minimal data on morphology and counts. Waite (1909) and Graham (1965) provided descriptions and accounts of behavior, but no meristic data. Strahan (1975) listed only ranges of counts and percentages of total length for certain body measurements for 13 specimens. We offer morphometry based on only the eight specimens available to us, but include counts on 22 specimens examined by Carl L. Hubbs in 1971 at the Australian Museum, Sydney.

Counts: Averages followed by ranges in parentheses, both sides counted: gill apertures 7 (all); prebranchial slime pores 17–18 (16–20); branchial pores 7 (6–8); trunk pores 48–49 (46–53); cloacal pores 3 (2–5); caudal pores 9 (6–11); total tail pores 12 (10–14); total slime pores 86 (83–90). Three fused cusps on each of the four multicusps; anterior unicusps 9 (8–11), posterior unicusps 8 (7–9); total cusps 46 (43–51).

Morphometry: Averages followed by ranges in parentheses, in thousandths of TL, for eight specimens: preocular length 60 (52–67); prebranchial length 225 (214–239); branchial length 76 (69–89); trunk length 550 (525–563); tail length 154 (135–168); maximum body depth including finfold 93 (84–102); excluding finfold 91 (81–102); body depth over cloaca 67 (57–74); tail depth 82 (77–91); body width at mid-prebranchial section 50 (46–55).

Dorsal profile of head sloping gently downward, face sloping at about a 45° angle; nasopharyngeal opening about equal to or slightly less than length of first barbel. Average length of first pair of barbels about 69% and second pair about 75% of the length of the third pair. Body rounded anteriorly, becoming more laterally compressed and deeper posteriorly; tail bluntly rounded, spatulate, its depth slightly less than greatest depth

of body (Table 1). Ventral finfold narrow and relatively short, its length about 30% of TL, extending from well behind midbody to cloaca.

Color of our specimens in preservative varies from light chocolate to dark brown; the most lightly colored one is strongly mottled anteriorly with small, irregular pale spots and patches. Waite (1909) stated that "the colour varies from blue to bluish violet [presumably fresh material]. Some examples show irregular white spots and markings; the ventral finfold and the margin of the tail may also be white." On our material, preserved at least ten years prior to our examination, the poorly developed finfold has a narrow pale margin on two specimens, but not on the other six; color is highly variable. Tail of one specimen is irregularly margined with pale areas; pale rings around most of the gill apertures and slime pores.

Small but plainly visible eyespots are present on all specimens. Removal of integument covering right eyespot of a specimen 577 mm TL reveals the embedded eye as elliptical (6.3 by 3.2 mm) and slanting forward ventrodorsally at about a 45° angle; pupil small, more rounded (about 1.9 by 1.4 mm).

Sensory canals, only as posterior series (in the specimens available to us), are located close behind eyespots (Fig. 4). Canals are readily identifiable on only three of eight specimens (488–655 mm TL) and only on the left side of largest one; they are similar in size, form, and arrangement to those of *E. strahani*. On two specimens (580 and 597 mm TL) positive identification of canals is prevented by presence of much scarring.

The anterior prebranchial slime pores on all specimens form a downsloping curve; a high incidence of irregular spacing of these pores occurs. On left side of four specimens, first or third pore is notably elevated or very closely spaced. On one specimen four pores form an almost-square pattern; all apparently lead from a single slime gland. In most *Eptatretus* from the Pacific Ocean, the usual number of branchial slime pores is one less than the number of GA, since ordinarily there is no pore associated with the PCD. In *E. cirrhatus* there is a high incidence of extra pores and irregular spacing of slime glands in the branchial region, especially near the PCD.

Posterior two or three GA, left side, curve gently downward on seven of eight specimens, but only on the right side of one. On a 480-mm juvenile female the normally confluent openings of the seventh GA and PCD are distinctly separate; such separation also occurs infrequently in other species of *Eptatretus*. Usually five, occasionally four, GP lie anterior to tip of DM. Length of DM 27% of TL, its width 13% (12–14%) of its length; somewhat flattened posteriorly, depth is 80% (75–88%) of its width. The shape of the tip of the DM varies somewhat from that of the other three species discussed herein (Fig. 3). Distance between tip of DM and branching of VA about 7.4% (4.8–10.8%) of DM length; VA usually greater in width than in length, in contrast to that of the other three species. No ABA lead off before branching of VA in the eight specimens available to us.

A 655-mm TL female contains about 50 large eggs, ranging from 29 to 32 mm long by about 10 mm in diameter; this is an unusually large number of maturing eggs. All are still in the mesentery which is attached to the body wall; terminal anchor filaments and hooks are not present on any egg.

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